



LONDON- WEST MIDLANDS ENVIRONMENTAL STATEMENT

Volume 5 | Technical Appendices

CFA9 | Central Chilterns

Water resources assessment (WR-002-009)

Water resources

November 2013

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Department for Transport

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1 Introduction

1.1 Structure of the water resources and flood risk assessment appendices

- 1.1.1 The water resources and flood risk assessment appendices comprise several parts. The first of these is a route-wide appendix (Volume 5: Appendix WR-001-000).
- 1.1.2 Specific appendices for each community forum area (CFA) are also provided. For the Central Chilterns community forum area (CFA9) these are:
 - a water resources assessment (i.e. this appendix); and
 - a flood risk assessment (Volume 5: Appendix WR-003-009).
- 1.1.3 Maps referred to throughout the water resources and flood risk assessment appendices are contained in the Volume 5, Water Resources and Flood Risk Assessment Map Book.

1.2 Study area

- 1.2.1 The study area covers a section of the Proposed Scheme approximately 6.1km in length in the Chiltern District. The south-eastern 2km of the Proposed Scheme comprises the northern section of the 13.3km long Chiltern tunnel. The north portal for the tunnel is located west of Hyde Heath, in Mantle's Wood. North of the tunnel portal the route will run in deep cutting for approximately 1.5km before entering the southern portal of the 1.2km long South Heath green tunnel. From the northern portal of the green tunnel, the route runs in cutting extending for approximately 1.5km to the boundary with the adjacent study area, the Dunsmore, Wendover and Halton area (CFA10) at Leather Lane.
- 1.2.2 The spatial scope of the assessment was based upon the identification of surface water and groundwater features within 1km of the centre line of the route, except where there is clearly no hydraulic connectivity. For surface water features in urban areas, the extent was reduced to 500m. Outside of these distances it is unlikely that direct impacts upon the water environment will be attributable to the Proposed Scheme. Where works extend more than 200m from the centre line, for example at stations and depots, professional judgement has been used in selecting the appropriate limit to the extension in spatial scope required. For the purposes of this assessment this spatial scope is defined as the study area. The main environmental features of relevance to water resources include:
 - the River Misbourne, a typical Chalk stream with winterbourne features, i.e. some sections in the upper reaches only flow at wet times of the year. The river also has a history of low flows;
 - the Cretaceous Chalk, a Principal aquifer (see Map WR-02-009 (Volume 5, Water resources and flood risk assessment Map Book);
 - public water supply groundwater abstractions and associated source protection zones (SPZ) located between Little Missenden and Great

Missenden in this study area and another in Amersham in The Chilterns and Amersham area (CFA8);

- one private licensed abstraction with an associated protection zone, and one unlicensed groundwater abstraction, both near Little Missenden;
- numerous identifiable ponds and drains located outside the route but within 1km of the centreline of the Proposed Scheme; and
- dry valleys associated with tributary catchments of the River Misbourne.

1.2.3 Key environmental issues relating to water resources include:

- potential impacts on groundwater flow towards public water supplies (PWS) from tunnelling activities;

1.2.4 Where a residual effect or mitigation for water resources impacts has a consequent effect on ecology this is discussed further in Volume 2, Central Chilterns (CFA Report 9) Section 7.

2 Stakeholder engagement

2.1.1 Discussions were held with the following stakeholders to inform the water resources assessment:

- the Environment Agency with regard to dewatering of the Little Missenden vent shaft during construction;
- Buckinghamshire County Council (as Lead Local Flood Authority);
- the Chilterns Society and Misbourne River Action Group regarding the River Misbourne; private licensees, requesting further information in a questionnaire to more accurately assess and understand any potential risks to the private abstraction; and
- Affinity Water and the Environment Agency, with regard to the PWS abstractions and the water resources management plan within this and the adjacent area (CFA8).

3 Baseline data

3.1 General

- 3.1.1 The following section provides a current description of water resources including surface water and groundwater.
- 3.1.2 All water bodies in this area fall within the Colne sub-catchment of the Thames River Basin District as defined under the Water Framework Directive¹ (WFD) and are covered by the River Basin Management Plan² (RBMP).

3.2 Surface water

- 3.2.1 All surface water features within 1km of the route are presented in Table 1.
- 3.2.2 The current surface water baseline and water features with codes listed in Table 1 are shown in Map WR-01-011 (Volume 5, Water resources and flood risk assessment Map Book). The map reference is in one of two forms. If the feature has a specific reference number then this is provided (e.g. a surface water crossing will be referenced as SWC-CFA09-01). If the feature has no specific reference its location on a specific map is provided (e.g. WR-01-011, D6) where D6 is a grid reference using the map specific grid.
- 3.2.3 The surface water features are based on the Environment Agency's Detailed River Network (DRN) with the addition of water bodies noted on the Ordnance Survey's '(OS) VectorMapDistrict'
- 3.2.4 Figure 1 shows the flows in the River Misbourne measured by the Environment Agency at their Little Missenden gauging station (reference number 39127) for the period since 2002. The gauging station is located on the boundary of this area with CFA8 to the south.
- 3.2.5 The River Misbourne is considered an over-abstacted catchment by the Environment Agency. Groundwater abstractions in the catchment began in 1901 and by 1997/98 abstractions were having such a marked impact on river flow that an Alleviation of Low Flow scheme was put in place leading to significant cuts in abstraction and a recovery of river flows. As shown in Figure 1, permanent flow was maintained throughout the period since 2002, a period that included the groundwater droughts of late 2006 and early 2012. This contrasts with the long term record on the National Rivers Flow Archive website which shows that the river has been dry for 5% of the period of summer flows, June to September. The Environment Agency is seeking to improve the river flow regime by further reducing net PWS abstractions. This process is ongoing and is likely to result in further changes to the hydrological regime of the River Misbourne and the aquifer.

¹ European Parliament and European Council, (2000),. Water Framework Directive - Directive 200/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, Strasbourg, European Parliament and European Council.

² Environment Agency, (2009), *River Basin Management Plan, Thames River Basin District*.

Figure 1: River Misbourne Flows at Little Missenden

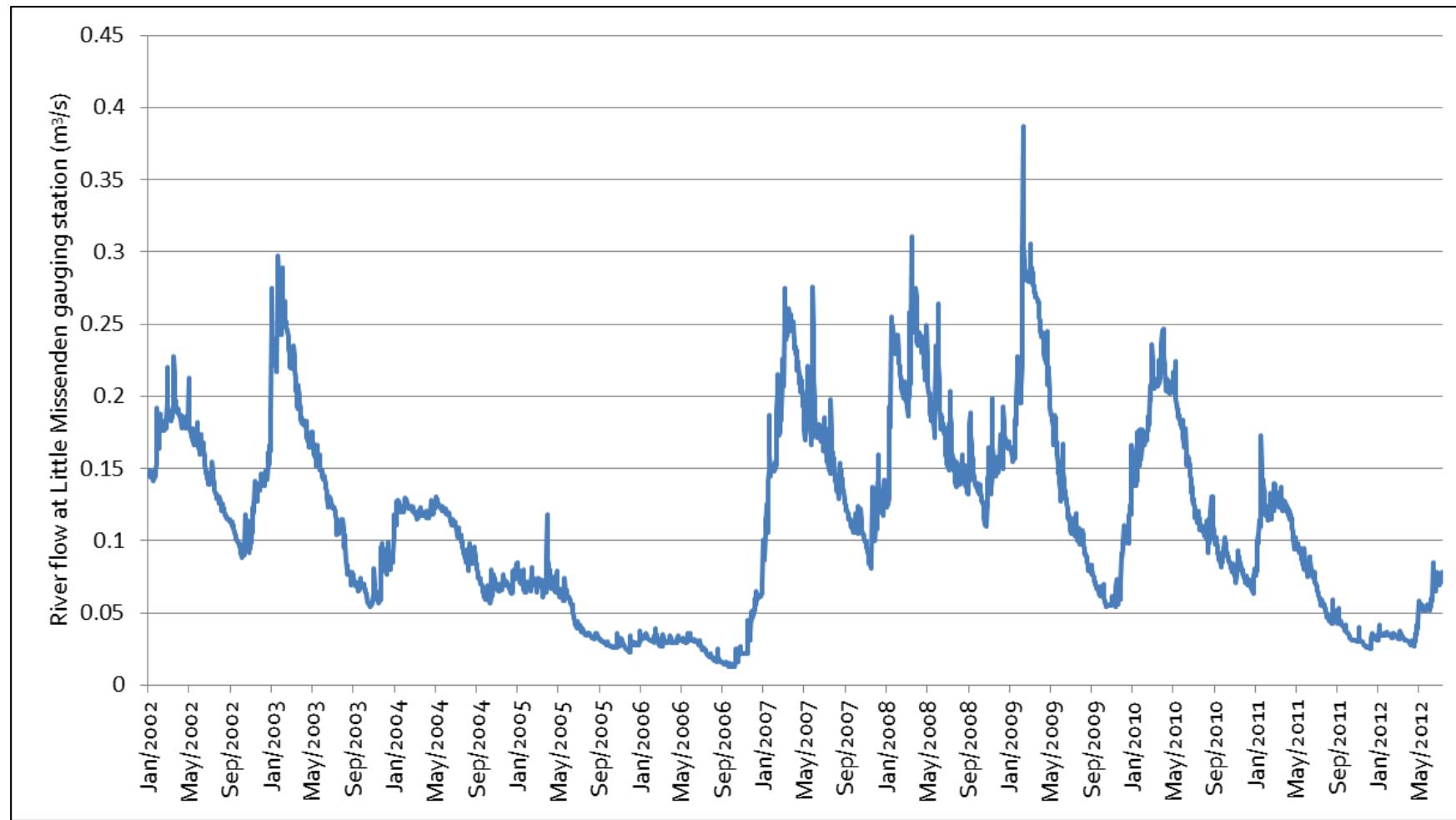


Table 1: Surface water features within 1km of the route in this study area

Water feature	Location description (Volume 5, Water resources and flood risk assessment Map Book map reference)	Watercourse classification ³	WFD water body and current overall status	WFD status objective (by 2027 as in RBMP)	Receptor value ⁴	Q95 ⁵ (m ³ /s)	Catchment area at crossing (km ²)	Notes
River Misbourne	The River Misbourne flows from north-west to south-east in the same general alignment as the route from Great Missenden to Little Missenden.	Main river	Misbourne (GB106039029830) Poor	Good potential	High	0.02	47.0	The route does not cross the River Missenden in this study area.
Unnamed pond – Parkview Cottage	Isolated pond approximately 350m south of the route at Parkview Cottage. (CFA09-P01)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The ponds are not connected to any other surface water features in the catchment.
Three unnamed drains – Little Missenden	Isolated drains approximately 400m-600m south of the route at Little Missenden.	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The drains are not connected to any other surface water features in the catchment.
Four unnamed ponds – Hyde Heath	Isolated ponds approximately 500m-900m north of the route near Hyde Heath. (CFA09-P02)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The ponds are not connected to any other surface water features in the catchment.

³Water-feature classifications: Section 113 of the Water Resources Act 1991 defines a main river as a watercourse that is shown as such on a main river map. Section 72 of the Land Drainage Act 1991 defines an ordinary watercourse as 'a watercourse that is not part of a main river'. Section 221 of the Water Resources Act 1991 defines a watercourse as including 'all rivers and streams, ditches, drains, cuts, culverts, dikes, sluices, sewers (other than public sewers) and passages through which water flows'. Main rivers are larger rivers and streams designated by Defra on the main river map and are regulated by the Environment Agency.

⁴For examples of receptor value, see Table 43 in the Scope and Methodology Report (SMR) Addendum, Volume 5: Appendix CT-001-000/2.

⁵Q95 is the flow which is exceeded for 95% of the time (i.e. it is a low flow and the river will only have flows less than this for 5% of the time).

Water feature	Location description (Volume 5, Water resources and flood risk assessment Map Book map reference)	Watercourse classification ³	WFD water body and current overall status	WFD status objective (by 2027 as in RBMP)	Receptor value ⁴	Q95 ⁵ (m ³ /s)	Catchment area at crossing (km ²)	Notes
Four unnamed ponds – Hyde End	Isolated ponds approximately 300m-900m north of the route, south of Hyde End. (CFA09-Po3)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The ponds are not connected to any other surface water features in the catchment.
Unnamed pond – The Hyde	Isolated pond approximately 300m north of the route at The Hyde. (CFA09-Po4)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The ponds are not connected to any other surface water features in the catchment.
Unnamed pond – King's Pond Cottage	Isolated pond approximately 100m north of the route at King's Pond Cottage. (CFA09-Po5)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The ponds are not connected to any other surface water features in the catchment.
Six unnamed ponds – South Heath	Isolated ponds approximately 200m-1km north of the route around South Heath. (CFA09-Po6)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The ponds are not connected to any other surface water features in the catchment.
Three unnamed ponds – Bury Farm	Isolated ponds approximately 250m-300m north of the route near Bury Farm. (CFA09-Po7)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The ponds are not connected to any other surface water features in the catchment.
Unnamed pond – Orchard Cottage	Isolated pond approximately 40m south of the route near Orchard Cottage. (CFA09-Po8)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The ponds are not connected to any other surface water features in the catchment.

Water feature	Location description (Volume 5, Water resources and flood risk assessment Map Book map reference)	Watercourse classification ³	WFD water body and current overall status	WFD status objective (by 2027 as in RBMP)	Receptor value ⁴	Q95 ⁵ (m ³ /s)	Catchment area at crossing (km ²)	Notes
Unnamed pond – Jenkin's Wood	Isolated pond approximately 50m north of the route at Jenkin's Wood. (SWC-CFA09-01) (CFA09-P09)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The ponds are not connected to any other surface water features in the catchment.
Unnamed pond – Park Farm	Isolated pond approximately 100m north of the route at Park Farm. (CFA09-P10)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The ponds are not connected to any other surface water features in the catchment.
Unnamed pond – Doctor's Grove	Isolated pond approximately 900m north of the route at Doctor's Grove. (CFA09-P11)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The ponds are not connected to any other surface water features in the catchment.
Two unnamed ponds and a drain – Springfield Farm	Isolated ponds and a drain approximately 200m -400m north of the route near Springfield Farm. (CFA09-P12)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The water features are not connected to any other surface water features in the catchment.

- 3.2.6 There are no surface water abstractions within 1km of the route in the study area⁶. There is the potential for unlicensed abstractions to exist, as a licence is not required for abstraction volumes below 20m³ per day.
- 3.2.7 The Environment Agency reports that there are no current consented surface water discharges in within 1km of the route in the study area.

3.3 Groundwater

- 3.3.1 A summary of the geological units present in CFA9 along with their hydrogeological characteristics is presented in Volume 2, CFA Report 9, Section 13.3.
- 3.3.2 Map WR-02-009 (Volume 5, Water resources and flood risk assessment Map Book) illustrates the spatial distribution of the uppermost superficial and bedrock formations within CFA09.
- 3.3.3 A schematic cross-section along the line of the route in this study area with regard to geological strata, groundwater elevations (average, where known) and the Proposed Scheme is presented in Figure 2.
- 3.3.4 The superficial deposits comprise Clay-with-Flints and the smaller outcrop of Head deposits, which are both considered unproductive strata with negligible quantities of groundwater. The thickness and properties of Clay-with-Flints is expected to vary over distances of a hundred metres or less but the vertical permeability is usually likely to be lower than that of the underlying Chalk. The Alluvium and the larger outcrop of Head deposits are designated as Secondary aquifers (both A and undifferentiated, respectively), although these deposits are limited to the course of the River Misbourne and not crossed by the route in this area.
- 3.3.5 The bedrock comprises Cretaceous White Chalk, which includes the Seaford Chalk, Lewes Nodular Chalk, New Pit Chalk and Holywell Chalk Formations.
- 3.3.6 Figure 3 presents the 1976 drought condition groundwater level contours for this study area and adjacent areas, using data from the 1978 Hydrogeological Map (Institute of Geological Sciences, 1978⁷). The contours are provided to indicate the regional direction of groundwater flow, which is to the south-east.
- 3.3.7 Figure 4 and Figure 5 present groundwater level hydrographs for two Environment Agency observation boreholes: the Mill House observation borehole (close to the boundary with CFA8, The Chalfonts and Amersham) and Hedgesparrow Cottage observation borehole (close to the boundary with CFA10, Dunsmore, Wendover and Halton). The maximum groundwater levels shown on these hydrographs range from approximately 104m AOD at the south-eastern end of the CFA to approximately 142m AOD at the north-western end. Comparing these values with the schematic cross-section on Figure 2, which illustrates the average water table only, it is concluded that the cuttings, South Heath green tunnel and Chiltern tunnel portal are likely to be above the maximum groundwater level.

⁶ Surface water abstractions for public supply are not included.

⁷ Institute of Geological Sciences, (1978), *South-West Chilterns hydrogeological map*.

Figure 2: Schematic cross section of geology and route in CFA9.

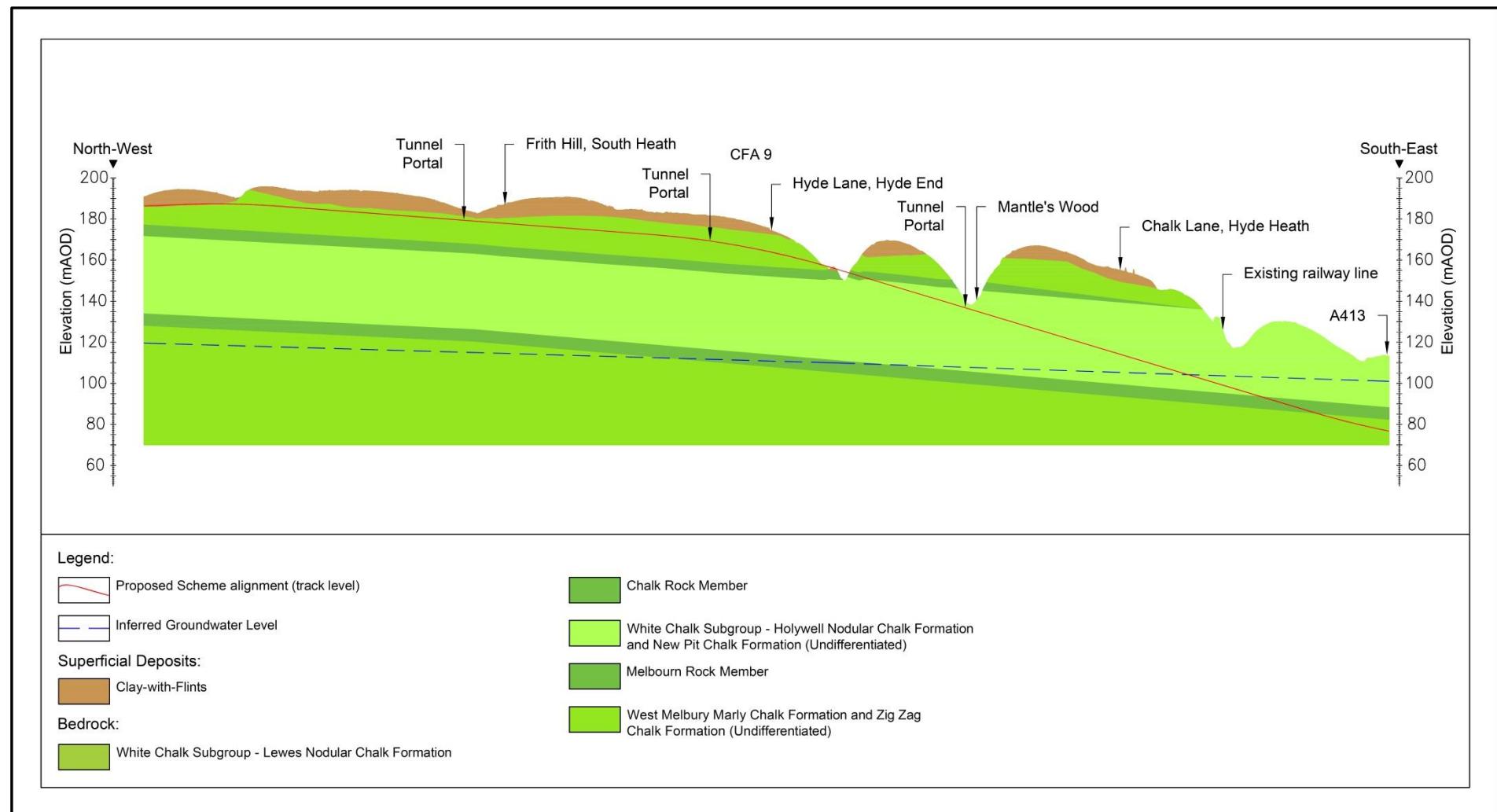
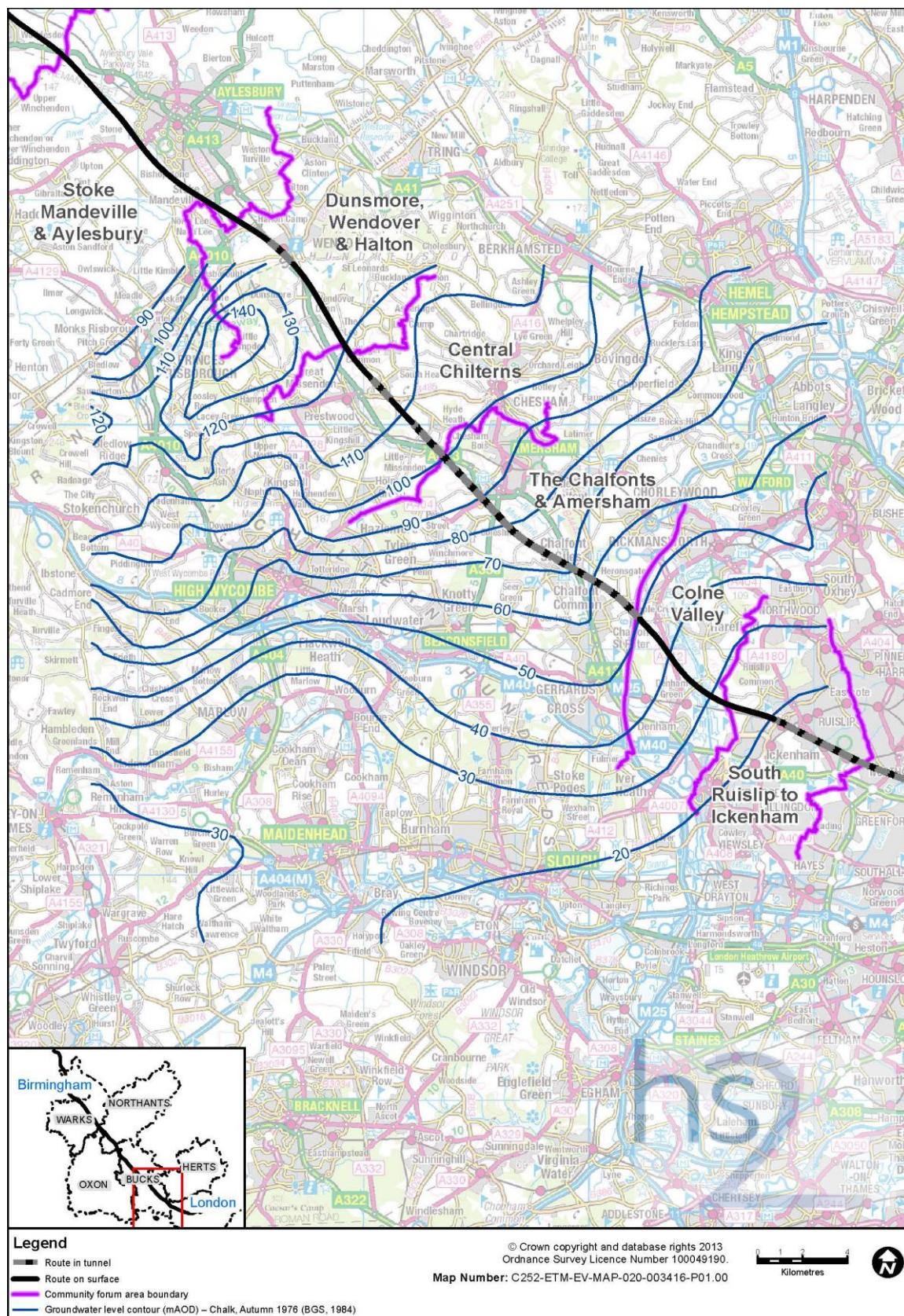


Figure 3: Groundwater elevation contours for this study area and the surrounding area



Appendix WR-002-009

Figure 4: Hydrograph for Mill House observation borehole (Environment Agency data)

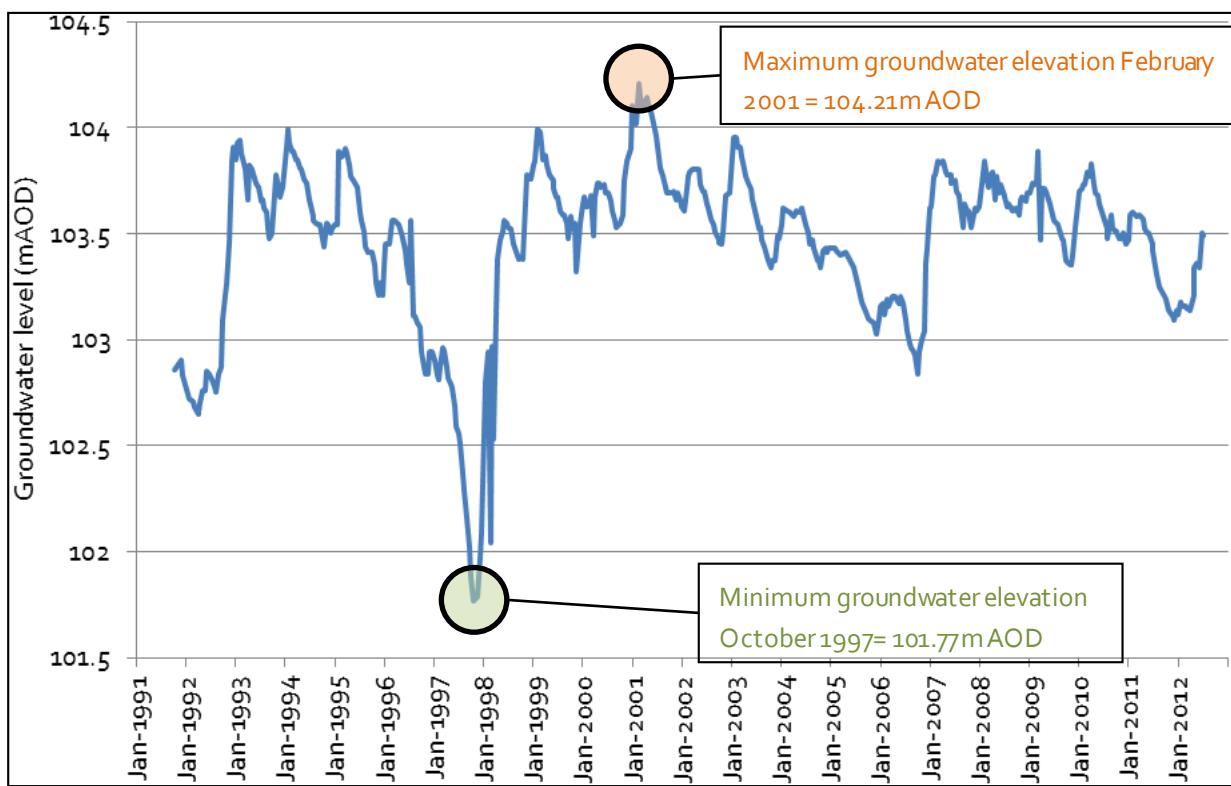
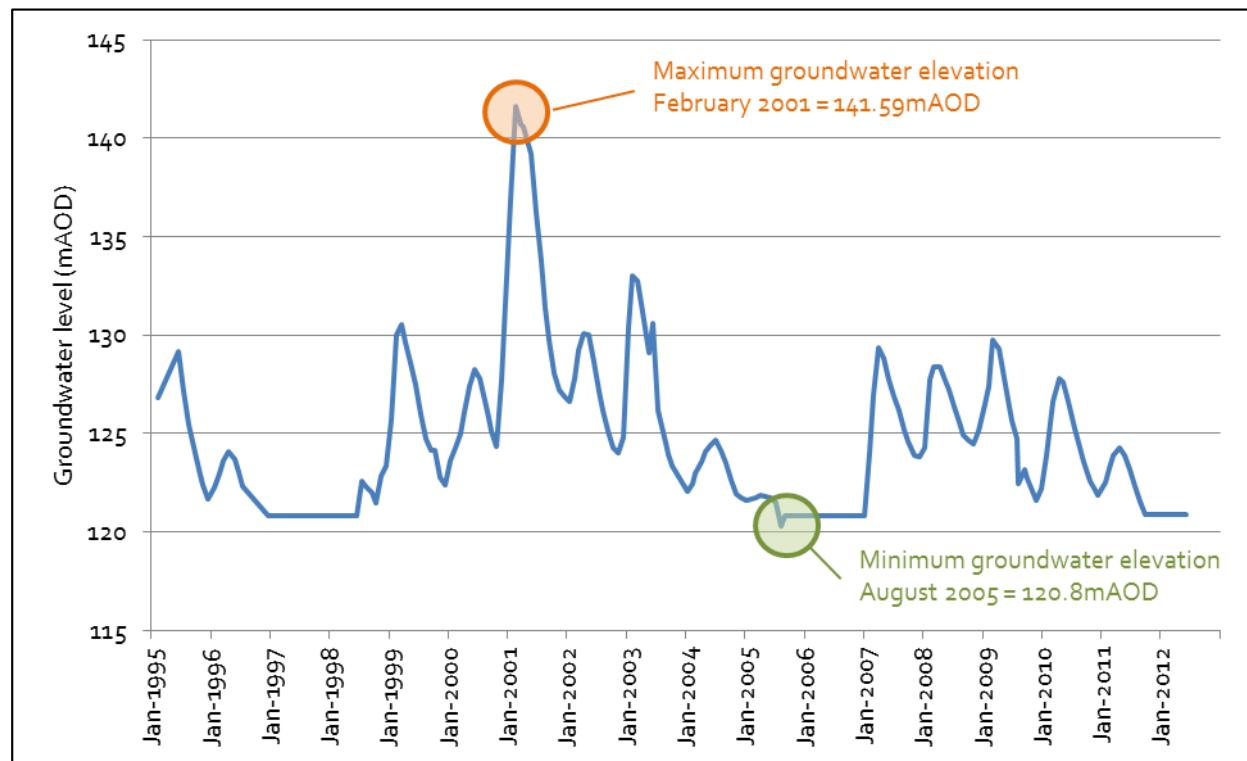


Figure 5: Hydrograph for Hedgesparrow Cottage observation borehole (Environment Agency data)



3.3.8 Table 2 summarises unlicensed and licensed groundwater abstractions (including PWS abstractions) or SPZ located within 1km of the route in the study area. There is the potential for further unlicensed abstractions to exist, as a licence is not required for abstraction volumes below 20m³ per day.

Table 2: Groundwater abstractions in this study area

Licence identifier (map reference number and Environment Agency reference)	Distance and direction from route (m)	Abstraction horizon	Maximum annual abstraction quantity (m ³)	Maximum daily abstraction quantity (m ³ /d)	Purpose	Number of boreholes
PWS (the reference number identifies the relevant SPZ⁸ on the maps)						
TH011 (licence identifier confidential)	SPZ ₂ and SPZ ₃ will be crossed by route in this study area. SPZ ₁ will be 975m (south-east), located in CFA8.	Chalk	2,555,000	18,184	PWS	Unknown
Private licensed abstractions						
28/39/28/0198 (GW6)	745m (south-west of route)	Chalk	8,182	44	Remedial river/wetland support, top up water.	One
Private unlicensed abstraction						
CFA09-GWUA02	685m (north-east of route)	Assumed to be Chalk.	Unknown	Unknown	Unknown	One

⁸ SPZ₁ is defined as the 50 day travel time from any point below the water table to the source. This zone has a minimum radius of 50m. SPZ₂ is defined by a 400 day travel time from a point below the water table with a minimum radius of 250m or 500m around the source, depending on the size of the abstraction and SPZ₃ is defined as the area around a source within which all groundwater recharge is presumed to be discharged at the source. In confined aquifers, the source catchment may be displaced some distance from the source. For heavily exploited aquifers, the final Source Catchment Protection Zone can be defined as the whole aquifer recharge area where the ratio of groundwater abstraction to aquifer recharge (average recharge multiplied by outcrop area) is >0.75. There is still the need to define individual source protection areas to assist operators in catchment management. Environment Agency (2013), *Groundwater protection: Principles and practice (GP3)*. August 2013, version 1.1.

3.3.9 A summary of groundwater discharge permits to groundwater directly or via land, within 1km of the route and their reference codes are listed in Table 3 and are shown in Map WR-02-009 (Volume 5, Water Resources and Flood Risk Assessment Map Book).

Table 3: Discharge consents to groundwater

Reference number	Permit identifier	Distance (and direction) from route (in metres)	Discharge type	Receiving strata/water body
CFA9WD10	CTCU.0013	60 (south-west)	Recreational and cultural; swimming pool discharge	Chalk (via land)
CFA9WD18	CTCU.0602	120 (north-east)	Domestic property - sewage discharges - final/treated effluent - not water company	Chalk (via land)
CFA9WD19	CTWC.1555	310 (south-west)	Domestic property - sewage discharges - final/treated effluent - not water company	Chalk (via land)
CFA9WD23	CTCU.0044	725 (north-east)	Domestic property - sewage discharges - final/treated effluent - not water company	Land
CFA9WD30	CATM.2708	210 (south-west)	Domestic property - sewage discharges - final/treated effluent - not water company	Clay-with-Flints (via land)
CFA9WD32	CTWC.0279	170 (south-west)	Domestic property - sewage discharges - final/treated effluent - not water company	Chalk (irrigation area)
CFA9WD37	CNTM.1512	40 (south-west)	Domestic property - sewage discharges - final/treated effluent - not water company	Chalk (via land)
CFA9WD42	CANM.0230	660 (south-west)	Domestic property - sewage discharges - final/treated effluent - not water company	Land
CFA9WD44	CANM.0654	350 (north-east)	Domestic property - sewage discharges - final/treated effluent - not water company	Land
CFA9WD45	CANM.0578	190 (north-east)	Domestic property - sewage discharges - final/treated effluent - not water company	Land

3.4 Surface water/groundwater interaction

3.4.1 Table 4 summarises the surface water/groundwater interactions within 1km of the route. There are 34 ponds recorded within 1km of the centre line of the route. Many of these are located in areas of Clay-with-Flints with water levels tens of metres above the underlying Chalk aquifer and it is therefore concluded they are perched. In contrast, the few ponds in the flood plain valley of the River Misbourne and the river itself are likely to interact with Chalk groundwater.

Table 4: Surface water/groundwater interaction

Location description	Distance and direction from route	Formation	Approximate elevation (metres above Ordnance Datum, m AOD)	Comments
River Misbourne (Map WR-01-011, A7 to I6)	Will not be crossed by route in this CFA. 275m (south at the CFA8/9 boundary) up to 1.25km for the majority of the route.	Alluvium/Chalk	105 – 130	Where flowing, the river is strongly gaining from groundwater in the study area with the exception of dry or very dry conditions, when groundwater levels are low. Flows above Amersham improved since 1998 due to reduction in groundwater pumping and dry conditions have not occurred at the Little Missenden gauge in the period since 2001. It should be noted that the elevation of groundwater is approximately 60m or more lower than the base of the tunnel.
Ponds at Little Missenden (Map WR-01-011, H7)	350 - 600m (south).	Alluvium/Chalk	105-110	Ponds are on the opposite bank of the River Misbourne to the tunnelled section of the Proposed Scheme. It should be noted that the elevation of groundwater is approximately 60m or more lower than the base of the tunnel.

3.5 Water dependent habitats

3.5.1 Table 5 summarises the water dependent habitats within 1km of the route.

3.5.2 Table 5 identifies where a water dependency exists. The assessment of impact on water dependent ecology receptors is found in the Ecology section in Volume 2, CFA Report 8 and 9, Section 7.

Table 5: Description of water dependent habitats

Name/Location	Distance from route	Description	Comments
River Misbourne (west of the Proposed Scheme) (Map WR-01-011, A7 to I6)	275m (at the CFA8/9 boundary) up to 1,250m for the majority of the route	Local Biodiversity Action Plan (BAP) habitat	This river is fed by groundwater from the Chalk aquifer.
Doctor's Meadow (south-west of the Proposed Scheme at Little Missenden) (Map EC-01-017, F10-G9)	630m	Basic ⁹ grassland	The meadow is bisected by the River Misbourne and may have some connectivity with the surface water and groundwater
Meadow behind Link Road car park (west of the Proposed Scheme at Great Missenden) (Map EC-01-018, E10-F10)	875m	Neutral grassland and damp meadow	The meadow is bisected by the River Misbourne. Some scrub and a small pond are present. The site is likely to have some connectivity with the surface water or groundwater

⁹ "Basic" and "Neutral" refer to the soil pH

4 Site specific surface water assessment

4.1 Summary of assessment

- 4.1.1 Table 6 summarises all potential impacts and effects to surface water features from the Proposed Scheme in the study area. Only those impacts and effects that are classed as significant are presented in Volume 2, CFA Report 9, Section 13.4.
- 4.1.2 Table 6 only includes water features which could potentially be impacted by the Proposed Scheme. Features such as isolated ponds and drains which will lie outside the construction footprint and area of impact of the Proposed Scheme, i.e. up to 1km of the Proposed Scheme, are not included. Details of these features are provided in Table 1.
- 4.1.3 The draft Code of Construction Practice (draft CoCP), referred to in Table 6, sets out the measures and standards of work that will be applied to the construction of the Proposed Scheme (see Volume 5: Appendix CT-003-000/1). These will provide effective management and control of the impacts during the construction period.
- 4.1.4 The route of the Proposed Scheme will not cross any watercourses in this area.

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Table 6: Summary of potential impacts to surface water

Surface water feature/receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact and effect	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
River Misbourne	High	Chiltern tunnel	The design will ensure a river crossing in this area will be avoided. Potential mitigation for ground settlement due to crossing in CFA8 will extend only 20m into CFA 9 and so is described in detail in CFA8.	Negligible Impact Neutral effect (Not significant)	Refer to Volume 2, CFA Report 8, Section 13 for details.	Negligible impact Neutral effect (Not significant)	None	None	Not applicable
Unnamed Pond – Orchard Cottage (CFA09-Po8)	Low	South Heath green tunnel	This pond will be adjacent to the route will be lost to construction and landscaping. No significant effect on water resources.	Negligible impact Neutral effect (Not significant)	No mitigation required.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (permanent)

Surface water feature/receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact and effect	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Unnamed Pond – Jenkin's Wood (CFA09-P09)	Low	South Heath cutting	This pond will be adjacent to the track and will be lost to construction and landscaping. No significant effect on water resources.	Negligible impact Neutral effect (Not significant)	No mitigation required.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (permanent)
Unnamed Pond – Park Farm (CFA09-P10)	Low	South Heath cutting	This pond will be adjacent to the track and will be lost to construction and landscaping. No significant effect on water resources.	Negligible impact Neutral effect (Not significant)	No mitigation required.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (permanent)
All water bodies	High	Construction sites	Potential for pollution or high suspended solids to enter surface water bodies.	Minor impact Moderate effect (Significant)	Appropriate mitigation as discussed in the draft CoCP, for polluting materials, management of earthworks and rate of surface runoff.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (temporary)

4.2 Detailed assessment

Drainage proposals

4.2.1 The Proposed Scheme has been designed to control impacts on the water environment during operation through appropriately designed surface drainage (i.e. incorporating sustainable drainage systems (SuDS)) and by following best practice pollution control guidance, as agreed with the Environment Agency. Interception ditches on the uphill side of the cuttings will be channelled into nearby balancing ponds which will act as soakaways. As a result, there will be no potentially significant impacts from land drainage identified during the operation phase.

4.2.2 Surplus rainfall in the cuttings will be piped or channelled to balancing ponds which will be sited between the route and the River Misbourne and which will also act as soakaways.

4.2.3 These balancing ponds are further discussed under groundwater (Section 5 of this report) as groundwater will be the receptor for the surface water drainage.

4.2.4 The construction of the vent shaft at Little Missenden and the Chiltern auto-transformer station will not significantly alter the local surface water flows due to the relatively small area of the surface alterations and therefore the consequential small alteration to the surface water catchment in this location. Surface water runoff in the post-development infrastructure will be discharged by infiltration. For further discussion of the impacts to groundwater see Section 5 of this report.

Highway drainage

4.2.5 Realignments of four minor roads (Hyde Lane, King's Lane, Frith Hill, and Leather Lane) and one major road (B485, Chesham Road), are required as part of the scheme in this area. These have the potential to cause minor temporary and permanent impacts on water quality in receiving watercourses/groundwater.

4.2.6 The receiving watercourses are the River Misbourne to which it is assumed Hyde Lane and Frith Hill outfall, via Great Missenden.

4.2.7 The road drainage at Chesham Road, Leather Lane and King's Lane is assumed to infiltrate into the ground through infiltration ponds/basins or as off the pavement runoff, and thus eventually will reach the water table in the White Chalk aquifer. Refer to Section 5.2 for further discussion.

4.2.8 Appropriate mitigation will be provided to address the risks to the receiving watercourses or water bodies (for both flow and water quality) and will be selected using the Design Manual for Roads and Bridges (particularly HA103/06)¹⁰ and the Construction Industry Research and Information Association (CIRIA) guidance¹¹.

¹⁰ Highways Agency (2013), *Design Manual for Roads and Bridges (DMRB)*; <http://dft.gov.uk/ha/standards/dmrb/index.htm>.

¹¹ Murnane, E., Heap, A. and Swain, A. (2006), *C648 Control of Water Pollution from Linear Construction Sites*. CIRIA, London, UK.

4.2.9 For the major roads, detailed assessments will be made during detailed design to inform the final discharge and treatment arrangements, using the guidance from the Design Manual for Roads and Bridges (Highways Agency, 2013). Residual impacts are likely to have neutral significance as a result.

5 Site specific groundwater assessment

5.1 Summary of assessment

5.1.1 Table 7 summarises the potential to hydrogeology (groundwater), abstractions, water dependent habitats and surface water/groundwater interactions. Only those impacts and effects that are classed as significant are presented in Volume 2, CFA Report 9, Section 13.4.

Table 7: Summary of potential impacts to groundwater receptors

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Hydrogeology (groundwater)									
Chalk Principal aquifer	High	Chiltern tunnel	<p>Dewatering during construction of the tunnel and cross passages could impact groundwater quality and flows.</p> <p>The tunnel will be approximately 20m below the water table at the boundary with CFA8 and will rise above the water table north of Lime Farm limiting the need for dewatering.</p>	<p>Minor impact</p> <p>Moderate effect</p> <p>(Significant)</p>	<p>The tunnel methodology will be selected to avoid significant groundwater ingress to the tunnels and the need for major dewatering.</p> <p>Any dewatering effluents (groundwater) at cross passages will be pumped for short periods (up to three months) and discharged to ground (e.g. through soakage areas) where possible, under consent from the Environment Agency.</p> <p>Ground improvement and groundwater control at some cross passages will be undertaken below ground.</p>	<p>Negligible impact</p> <p>Neutral effect</p> <p>(Not significant)</p>	None	<p>Negligible impact</p> <p>Neutral effect</p> <p>(Not significant)</p>	Construction (temporary)

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Chalk Principal aquifer	High	Chiltern tunnel Little Missenden vent shaft Cross passages	The cross-sectional areas of the tunnel, vent shaft and cross passages are relatively small in comparison with the assumed effective thickness of the Chalk aquifer. Groundwater flow is roughly parallel to the route so there is not expected to be a major impact on water levels due to the obstruction of groundwater flow. There is only a short section of route below the water table.	Negligible impact Neutral effect (Not significant)	None required.	Negligible impact Neutral effect (Not significant)	None	None	Not applicable

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Chalk Principal aquifer	High	Little Missenden vent shaft and Chiltern auto-transformer station	Groundwater flows and discharges to the River Misbourne will be reduced by dewatering at the vent shaft.	Moderate impact Large effect (Significant)	Dewatering will take place from within the shaft walls and dewatering effluent will be re-injected into the aquifer nearby thus avoiding impacts away from the construction area.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (temporary)
Chalk Principal aquifer	High	Five construction sites, including South Heath mid-point auto-transformer station	Potential for accidental spills of oils and chemicals stored on site via surface infiltration or runoff.	Minor impact Moderate effect (Significant)	With implementation of the draft CoCP and best practice, there should be sufficient mitigation in place to avoid adversely impacting water quality.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (temporary)
Chalk Principal aquifer	High	Eight overbridges	Potential for accidental spills of oils and chemicals used for construction or impact on flows/quality as a result of the foundations. Foundations are, however, unlikely to be below the water table.	Negligible impact Neutral effect (Not significant)	With implementation of the draft CoCP and best practice, there should be sufficient mitigation in place to avoid adversely impacting water quality.	Negligible impact Neutral effect (Not significant)	None	None	Construction (temporary)

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Chalk Principal aquifer	High	Balancing ponds	Potential impact on groundwater flow or quality from the drainage water. Further information is provided in Section 5.2 of this report.	Negligible impact Neutral effect (Not significant)	None required.	Negligible impact Neutral effect (Not significant)	None	None	Not applicable

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Chalk Principal aquifer	High	Twelve stockpiles	<p>Potential impact on groundwater quality in the Chalk aquifer from leaching of pollutants in excavated material in stockpiles located throughout the study area, generally within 250m of the Proposed Scheme.</p> <p>Excavated material from cuttings, however, is unlikely to be contaminated and in most cases will contain a high proportion of moderate to low permeability Clay-with-Flints. Almost all of the stockpiles will be placed above natural Clay-with-Flints superficial deposits which will further protect the underlying Chalk groundwater quality.</p>	<p>Negligible impact</p> <p>Neutral effect (Not significant)</p>	<p>Suitable quality criteria will be defined prior to material being placed. The draft CoCP, Section 15, defines the controls and guidance that should be followed in order to obtain agreement with the Environment Agency to obtain an appropriate permit or exemption from permitting.</p> <p>Monitoring of water quality will also be implemented as outlined in the draft CoCP, Section 16.</p>	<p>Negligible impact</p> <p>Neutral effect (Not significant)</p>	None	None	Not applicable

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Abstractions									
PWS (TH011, TH316)	High	Chiltern tunnel (south of Lime Farm) Little Missenden vent shaft Cross passages	Tunnelling and piling/diaphragm wall construction could have the potential to impact on groundwater quality due to the migration of fluids or suspended bedrock particles giving rise to raised turbidity, particularly where fissures are connected to high value receptors such as PWS.	Moderate impact Large effect (Significant)	The route avoids SPZ1 and there is limited work below the water table in SPZ2. Additional mitigation is required during the tunnelling period to avoid unplanned withdrawal of public water supplies and potential impacts on customers. Monitoring will inform further mitigation requirements, if required.	Moderate impact Large effect (Significant)	A hierarchy of further mitigation, as discussed in Volume 2, CFA Report 9, Section 13.3, if monitoring indicates this will be necessary.	Neutral (Not significant)	Construction (temporary)
PWS (TH011, TH316)	High	Chiltern tunnel (north of Lime Farm) Chiltern tunnel north cutting South Heath green tunnel South Heath cutting	Potential impact to groundwater flows and quality at abstractions. To the north of Lime Farm the route is expected to be above the water table and the risk of impacts on groundwater quality, particularly at PWS, due to increased turbidity is reduced. There could, however, still be potential for quality to be impacted adversely.	Minor impact Moderate effect (Significant)	Monitoring will inform further mitigation requirements, if needed.	Minor impact Moderate effect (Significant)	A hierarchy of further mitigation, as discussed in Volume 2, CFA Report 9, Section 13.3, if monitoring indicates this will be necessary.	Neutral (Not significant)	Construction (temporary)

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
PWS (TH011, TH028, TH316)	High	Balancing ponds	<p>Potential for infiltration from balancing ponds to pollute Chalk groundwater in areas of SPZs.</p> <p>SPZ1, however, is generally avoided. Water in track drainage or from intercepted land drainage is not expected to contain pollutants and the base of pond material and unsaturated thickness of the Chalk will provide some attenuation of any constituents within the drainage water.</p> <p>See Section 5.2 of this report for further discussion.</p>	<p>Negligible impact</p> <p>Neutral effect (Not significant)</p>	None required.	<p>Negligible impact</p> <p>Neutral effect (Not significant)</p>	None	None	Not applicable

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
PWS (especially TH011)	High	Two small (162 and 210m ²) stockpiles at the Mantles Wood vent shaft.	Potential impact on groundwater quality in the Chalk aquifer within the SPZ2 for TH011 from leaching of pollutants in excavated material in stockpiles located where there are no superficial deposits overlying the Chalk aquifer. Excavated material from shaft construction is, however, unlikely to be contaminated.	Negligible impact Neutral effect (Not significant)	Suitable quality criteria will be defined prior to material being placed. The draft CoCP, Section 15, defines the controls and guidance that should be followed in order to obtain agreement with the Environment Agency to obtain an appropriate permit or exemption from permitting. Monitoring of water quality will also be implemented as outlined in the draft CoCP, Section 16.	Negligible impact Neutral effect (Not significant)	None	None	Construction (permanent)

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Private abstractions GW6 CFA09- GWUA02	High	Chiltern tunnel Cross passages	There will be a very small risk of a potential impact to groundwater flows and quality at abstractions. Private abstractions are lower yielding with smaller inner protection zones and GW6 is used for surface water top up. The route will not pass within the inner or outer protection zones of either abstraction. Information regarding GW6 indicates that it is not used as a potable supply. The abstractions are also not down-gradient of the route.	Minor impact Slight effect (Negligible)	Application of the draft CoCP will ensure no adverse impacts to groundwater quality or flows.	Negligible impact Neutral effect (Negligible)	None	Negligible impact Neutral effect (Negligible)	Construction (Permanent)

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Surface water/groundwater interaction									
River Misbourne	High	Little Missenden vent shaft	Potential change in groundwater outflow to river due to tunnelling or dewatering during the construction of the vent shaft at Little Missenden.	Minor impact Moderate effect (Significant)	The tunnel construction methodology will be selected to avoid significant groundwater ingress to the tunnels and the need for major dewatering. Any dewatering effluents (groundwater) at cross passages will be pumped for short periods (up to three months) and discharged to ground (e.g. through soakage areas) where possible, under consent from the Environment Agency. Ground improvement and groundwater control at some cross passages will be undertaken below ground. Dewatering will take place from within the shaft walls and dewatering effluent will be re-injected into the aquifer nearby thus avoiding impacts away from the construction area.	Negligible impact Neutral effect (Not significant)	None	None	Construction (temporary)

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
River Misbourne	High	Chiltern tunnel Chiltern tunnel north cutting South Heath green tunnel South Heath cutting	Turbidity or other contaminants from construction could affect surface water quality. Times of travel, however, for the natural emergence of groundwater at surface water features are likely to be long enough for attenuation (combining dispersion, diffusion and dilution) during migration to points of natural emergence to reduce turbidity to levels that are unlikely to affect surface water quality.	Negligible impact Neutral effect (Not significant)	None required.	Negligible impact Neutral effect (Not significant)	None	None	Not applicable

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Water dependent habitats									
River Misbourne BAP (west of the Proposed Scheme).	High	Chiltern tunnel Chiltern tunnel north cutting South Heath green tunnel South Heath cutting Little Missenden vent shaft	As there will be no significant effect on the river flows/levels, there will be no adverse impact to the ecological status of this BAP.	Negligible impact Neutral effect (Not significant)	None required.	Negligible impact Neutral effect (Not significant)	None	None	Not applicable

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Doctor's Meadow (south-west of the Proposed Scheme at Little Missenden).	Moderate	South Heath cutting	<p>This meadow is in connectivity with the River Misbourne and potentially groundwater.</p> <p>As there will be no adverse effect to the groundwater levels or the River Misbourne at Doctor's Meadow, there will be no adverse effect to the meadow as a result of changes to the hydraulic and hydrogeological regime.</p>	<p>Negligible impact</p> <p>Neutral effect (Not significant)</p>	None required.	<p>Negligible impact</p> <p>Neutral effect (Not significant)</p>	None	None	Not applicable

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Meadow behind Link Road car park (west of the Proposed Scheme at Great Missenden).	Moderate	Chiltern tunnel	<p>This meadow is in connectivity with the River Misbourne and potentially groundwater.</p> <p>As there will be no adverse effect to the groundwater levels or the River Misbourne at the Meadow, there will be no adverse effect to the meadow as a result of changes to the hydraulic and hydrogeological regime.</p>	<p>Negligible impact</p> <p>Neutral effect (Not significant)</p>	None required.	<p>Negligible impact</p> <p>Neutral effect (Not significant)</p>	None	None	Not applicable

5.2 Detailed assessment

Balancing ponds/infiltration basins

5.2.1 The study area will contain a number of balancing ponds that rely on infiltration to the ground as a means of discharge. The majority of the proposed infiltration basins will only handle land drainage runoff and as such the water quality will be similar to that in the existing drainage reaching the underlying aquifer. The distribution of these basins along the route will not change the overall pattern of recharge and so it is concluded there will be negligible impact on groundwater flow or quality in the Chalk aquifer.

5.2.2 A smaller number of infiltration basins will act as the point of discharge for the track drainage from the cuttings. The runoff from rainfall within the cuttings will partly infiltrate through catchpits with the remainder passing out of the ends of the cuttings to the basins. The water quality of infiltrating track drainage is not expected to be substantially different from land drainage since the surface layer in the basin or catchpit will trap sediment and particulates. Thus, although some redistribution of the infiltration into the aquifer will occur from track drainage, the catchment areas of the cuttings will be small and it is considered that this will be likely to have negligible impact on groundwater flow or quality in the Chalk aquifer.

5.2.3 There will be three infiltration basins that will drain into the White Chalk groundwater. These will be adjacent to Leather Lane, King's Lane and Chesham Road. The basins that will be associated with the Leather Lane and King's Lane highways drainage will be connected to minor roads that are unlikely to generate concentrations of pollutants that will significantly adversely affect groundwater quality. Further to this the nearest SPZ1 for PWS will be 3.45km south of the Leather Lane drainage and 4.53km south-east of the King's Lane drainage, thereby providing sufficient attenuation and dilution within the aquifer to ensure the PWS are not significantly affected. Whilst the highways drainage for Chesham Road will be associated with a major road, the nearest SPZ1 for PWS will be 3.92km south-east and therefore attenuation and dilution will ensure any concentrations to reach the SPZ1 will not adversely affect the groundwater quality.

5.2.4 The controls on the potential impact from selected infiltration basins to groundwater quality in the underlying aquifer and at PWS abstractions are presented in Table 8. This shows that the thickness of the unsaturated zone is expected to range from 8m to 67m. It is considered that, in conjunction with the soil and vegetation layer on the basin floor, this thickness will be sufficient to provide moderate to substantial attenuation for constituents within the drainage water before drainage water enters the water table. The locations of the infiltration basins within the SPZ will allow further, substantial times of travel to the actual PWS boreholes. In addition, detailed design of the infiltration basin will follow CIRIA C697¹² and CIRIA R156¹³, which states that groundwater quality must not be impacted by infiltrating water in accordance with the requirements of the WFD and the Groundwater Protection, Policy and

¹² Construction Industry Research and Information Association, CIRIA, (2007), Report 697; *The SUDS manual*.

¹³ Construction Industry Research and Information Association, CIRIA, (1996), Report R156; *Infiltration Drainage: Manual of Good Practice*.

Practice (GP3) documentation (Environment Agency, 2013¹⁴). It is therefore concluded that the assessment shows there will be negligible impact on water quality at PWS boreholes.

Table 8: Summary of controls on potential impacts to groundwater quality from drainage infiltration ponds

Location of basin	Approximate Chalk groundwater level (m AOD)	Approximate ground level (m AOD)	Unsaturated thickness (m)	Potential impacts to groundwater quality
Mantle's Wood	107	135 – 165	8 – 18	Eastern half overlying Head deposits. Just impinges on total SPZ for PWS TH028, located approximately 14km to the south-east and avoids any SPZ2 or SPZ1.
Hedgemoor	109.5	135 – 140	25.5 – 30.5	No superficial deposits Overlying SPZ2 for PWS TH011, located approximately 5.5km down-gradient to the south-east.
East of River Misbourne at Great Missenden	116	130 – 135	14 – 19	No superficial deposits Overlying total SPZ for PWS TH316 located 2.5km to the south-east and avoids any SPZ2 or SPZ1.
North of Havenfield Wood	118	180 – 185	62 – 67	No superficial deposits Overlying total SPZ for PWS TH316 located 3.5km to the south-east and avoids any SPZ2 or SPZ1.
North of Leather Lane	119	180 – 185	61 – 66	No superficial deposits Overlying total SPZ for PWS TH316 located 3.8km to the south-east and avoids any SPZ2 or SPZ1.

¹⁴ Environment Agency, (2013), *Groundwater protection: Principles and practice (GP3)*, August 2013, Version 1.1.

Assessment of cuttings

5.2.5 The cuttings and design features in this study area are presented in Table 9. Since the Clay-with-Flints is not classed as an aquifer, interception of any seepages that may occur towards the top of the side slopes is assessed as not having a significant impact on water resources.

Table 9: Summary of cuttings and design features and their potential impact on groundwater in this study area

Cutting name	Geology penetrated	Groundwater elevation	Potential impact on groundwater resources	Mitigation requirements
Chiltern tunnel north cutting	Chalk Principal aquifer	Water table below the cutting	No interception of Chalk groundwater.	Not required
South heath green tunnel	Chalk Principal aquifer	Water table below the tunnel	No interception of Chalk groundwater.	Not required
South Heath cutting	Chalk Principal aquifer	Water table below the cutting	No interception of Chalk groundwater.	Not required
Rocky Lane south cutting	Chalk Principal aquifer	Water table below the cutting	No interception of Chalk groundwater.	Not required

6 References

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